Short

A Dictionary of Aerosol Remote Sensing Terms

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Let's look at 3 kinds of properties that are important to understand about aerosols

Physical Properties

Optical Properties

Chemical Properties

These two types of properties are very closely linked in remote sensing because we infer the Physical properties from Optical measurements

Because we measure the entire column our properties represent the mean particle characteristics

Physical Properties

Aerosol Amount

- AOD - Aerosol Optical Depth
- AOT - Aerosol Optical Thickness

These optical measurements of light extinction are used to represent aerosol amount in the entire column of the atmosphere.

Physical Properties

Aerosol Amount

AOD is a unitless value.

Sample AOD values:
0.02 - very clean isolated areas.
0.2 – fairly clean urban area
0.4 – somewhat polluted urban area
0.6 – fairly polluted area
1.5 – heavy biomass burning or dust event

Moderate AOD ~0.40
Near Mt. Abu, India

Photo courtesy of Brent Holben

Heavy AOD
Below the planetary boundary layer

Photo courtesy of Brent Holben

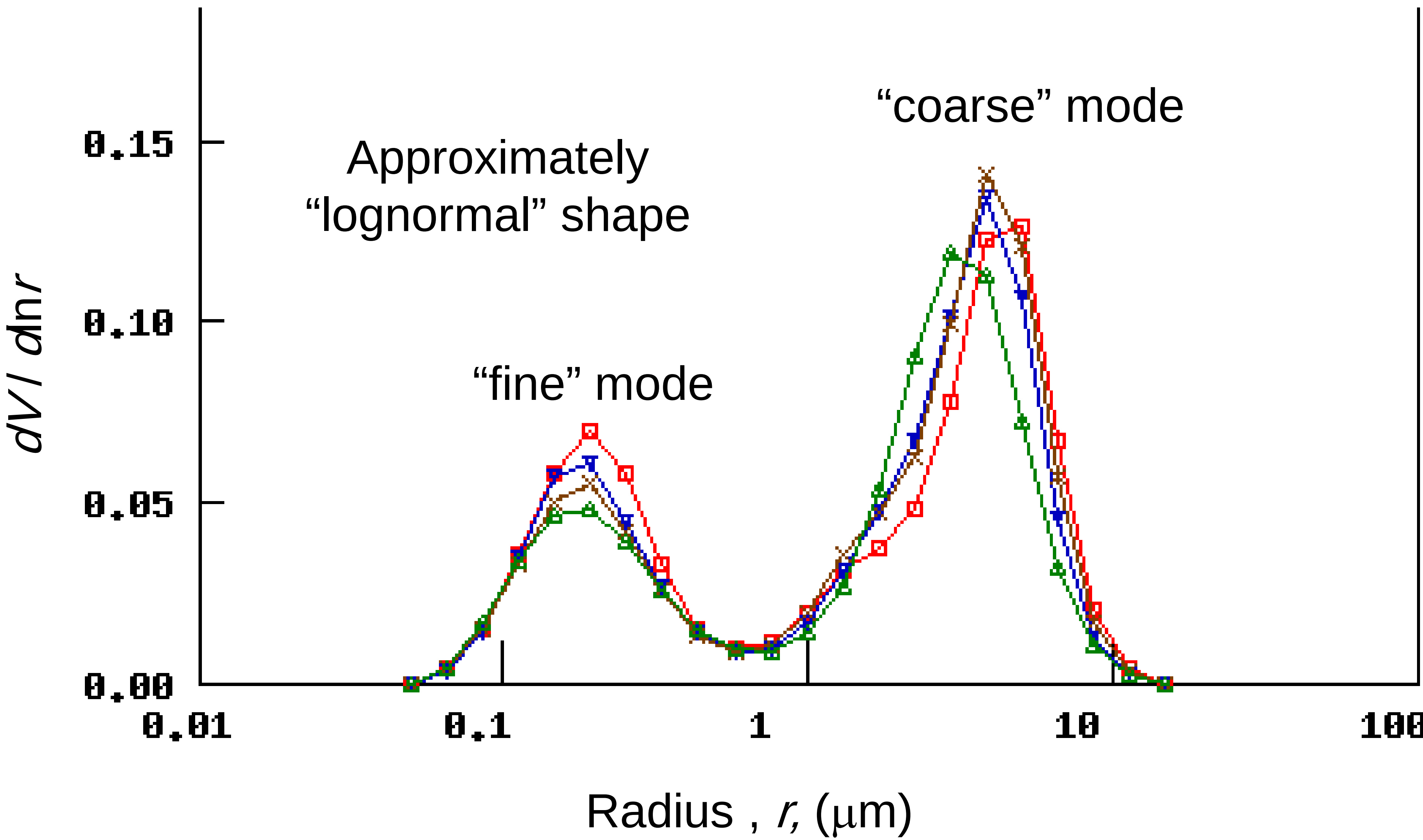
Physical Properties

Particle Size Distribution - There is an assumption, based on many years of measurements, that aerosols in the optically active size ranges are best represented as a bimodal distribution. The aerosol size distribution can be represented as a volume or number distribution.

The mode representing the small (fine mode) aerosol has a size distribution centered on radii between 0.1 and 0.25 microns.

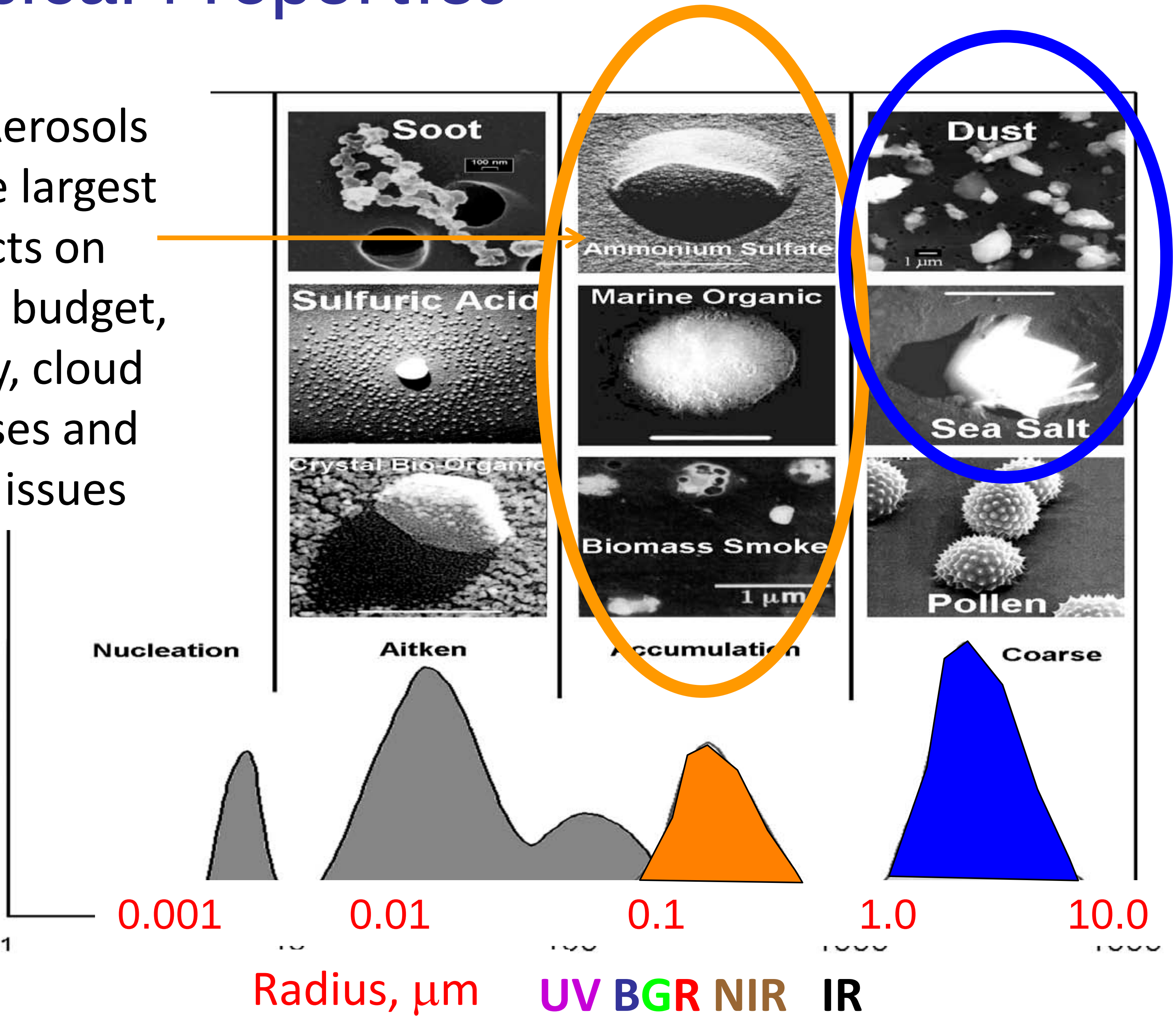
The mode representing the large (coarse mode) aerosol has a size distribution centered on radii between 1 and 2.5 microns.

Size Distribution



Physical Properties

These Aerosols have the largest impacts on radiative budget, visibility, cloud processes and health issues



Why is Size Distribution Important?

A result of a combustion process

Smoke

(Biomass Burning) 〉 Small

Industrial Pollution

NATURAL – A result of a wind or erosion process

Sea Salt

Dust 〉 Large

Physical Properties

Fine Fraction

A simple ratio of the volume of fine particles to the total volume of particles.

Values range from 0 - 1

Fine AOD

The fraction of light extinction due to particles in the fine mode.

Total AOD x Fine Fraction

Physical Properties

Aerosol Amount - AOD, AOT

- $PM_{2.5}$ - particles of less than 2.5 µm aerodynamic diameter
  These can penetrate deeply into the lungs

$PM_{2.5}$ concentration at ground level is an important parameter for air quality studies.

- Aerosol Mass Concentration - Mass / cm^2 (MODIS Units)

- CCN (Cloud Condensation Nuclei) Concentration.

These are particles that act as condensation surfaces and encourage water droplet formation within clouds.

Physical Properties

Particle shape - spherical, spheroid, non-spherical

Particle shape may:

•give some information of the source and age of the particle

• influence climate processes

• affect how active aerosols are in the lungs

Optical Properties

Optical properties are important for several reasons

1) Their effect on the radiative balance of the Earth's environment

1) Their effect on heating of the atmospheric column which can change circulation and affect the water cycle

2) Visibility

Optical Properties

Light Scattering
Light Absorption

These quantities are difficult
to separate and measure individually

Extinction = Scattering + Absorption

Single Scattering Albedo – a measure of how absorbing or scattering we consider the mass of aerosol particles.

$$\omega_o = \frac{AOT_{scatter}}{AOT_{scatter} + AOT_{absorption}}$$

Values of .85 are considered very absorbing
Values of .95 are considered very non-absorbing

Optical Properties

Complex Index of Refraction

Real Component - refers to light bending

Imaginary Component - refers to light absorption due to the material

Radiative Transfer

The physics and mathematics of how radiation passes through a medium that may contain any combination of scatterers, absorbers, and emitters.

Aerosol Inversion

Using the measured optical properties to infer the physical characteristics of the Aerosol.

This is performed by an inversion of the Radiative Transfer Equations.

Aerosol Inversion

Usually we start with the object and obtain the measured properties.

An inversion works backwards.
We start with a set of measured properties that are used to determine the physical object.

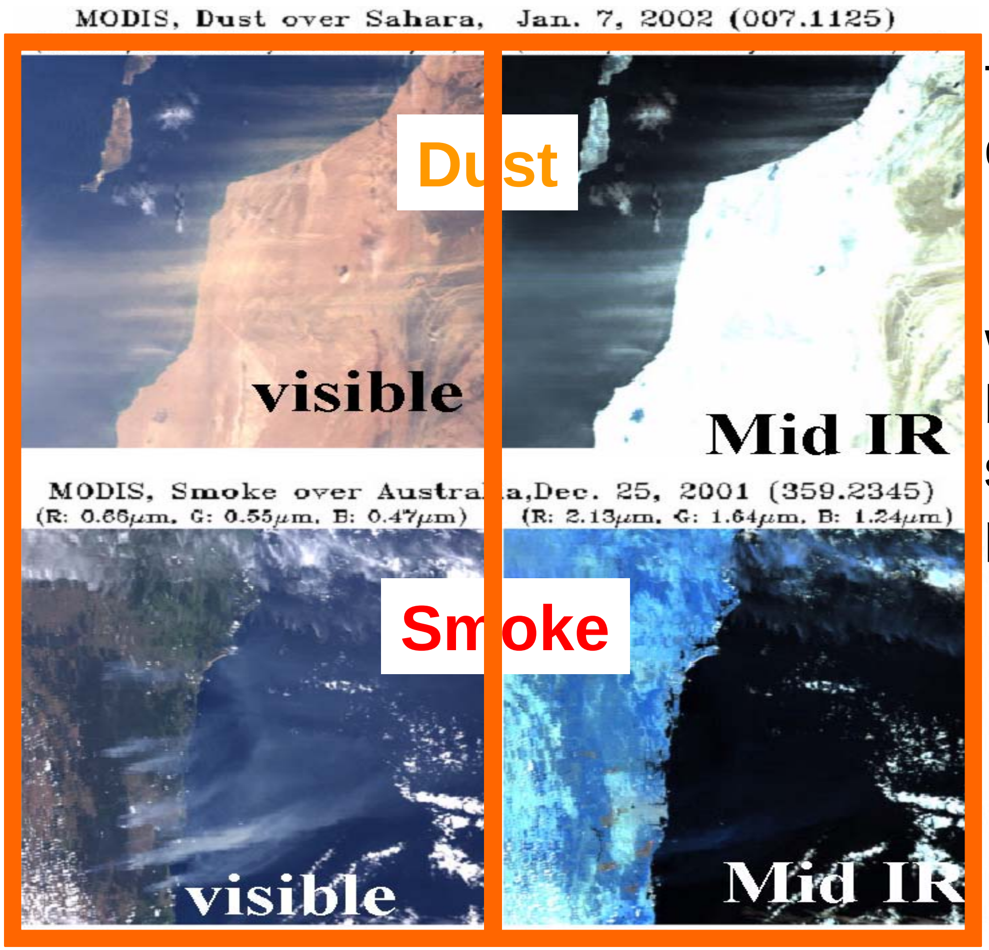
Since there are many possible physical conditions that can produce the measurements we use as our starting point several assumptions are made in an aerosol inversion.

End Part 1

Spectral optical properties of aerosol

Both dust and smoke interact with the shorter wavelengths reflecting light back to the sensor.

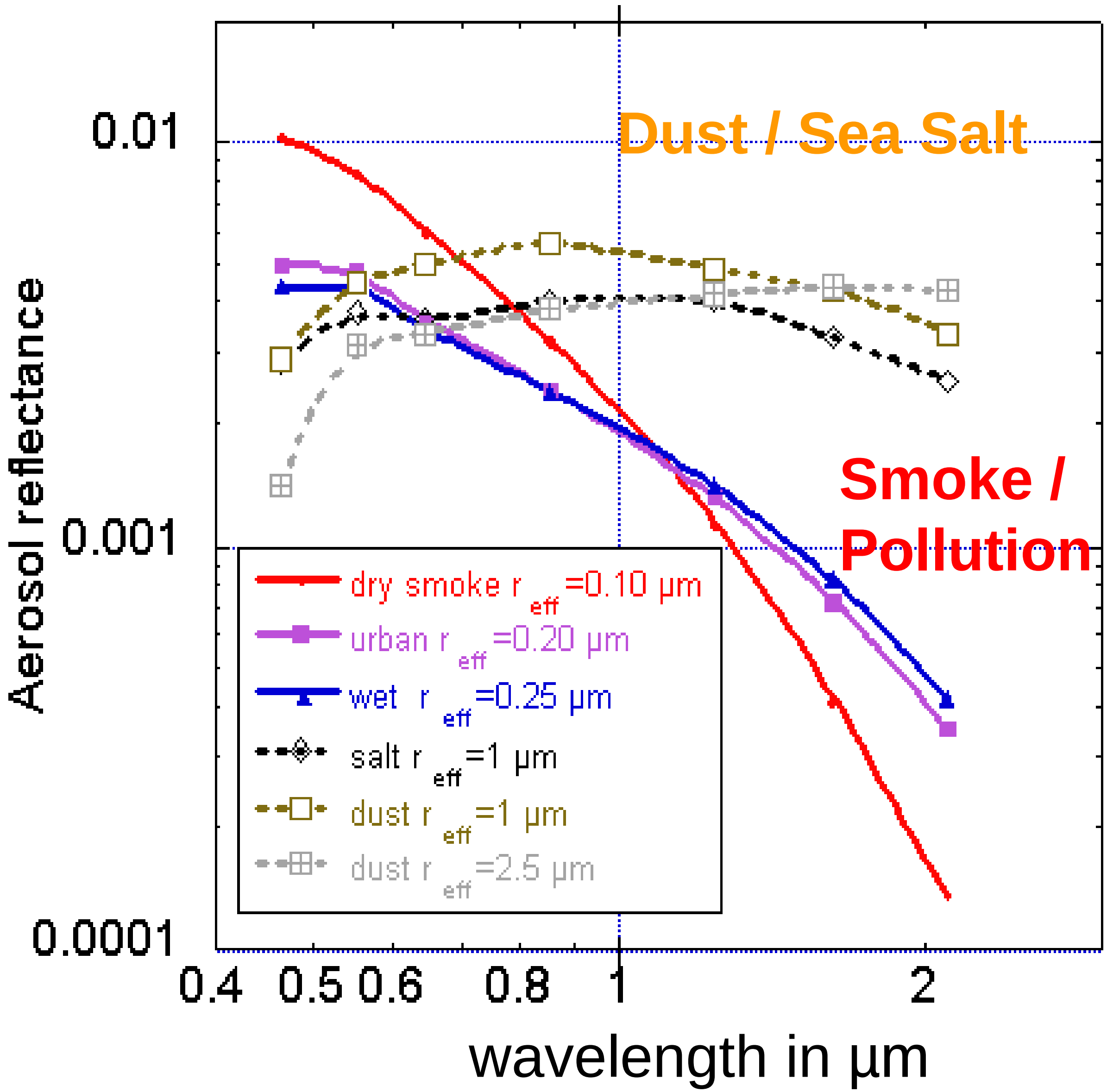
This distinction is made possible by the wide spectral range of the MODIS sensor.



from Y. Kaufman

The larger dust particles interact with the longer infrared wavelengths but not the smaller smoke particles which remain invisible.

Spectral optical properties of aerosol



Here you can see the spectral response of the large and small particles.

Physical Properties

Angstrom Exponent

The Angstrom exponent is often used as a qualitative indicator of mean aerosol particle size
Values greater than 2 - small particles
Values less than 1 – large particles

For measurements of optical thickness
$\tau_{\lambda 1}$ and $\tau_{\lambda 2}$ taken at two different wavelengths λ_1 and λ_{21}

$$\alpha = -\frac{\ln \frac{\tau_{\lambda_1}}{\tau_{\lambda_2}}}{\ln \frac{\lambda_1}{\lambda_2}}$$

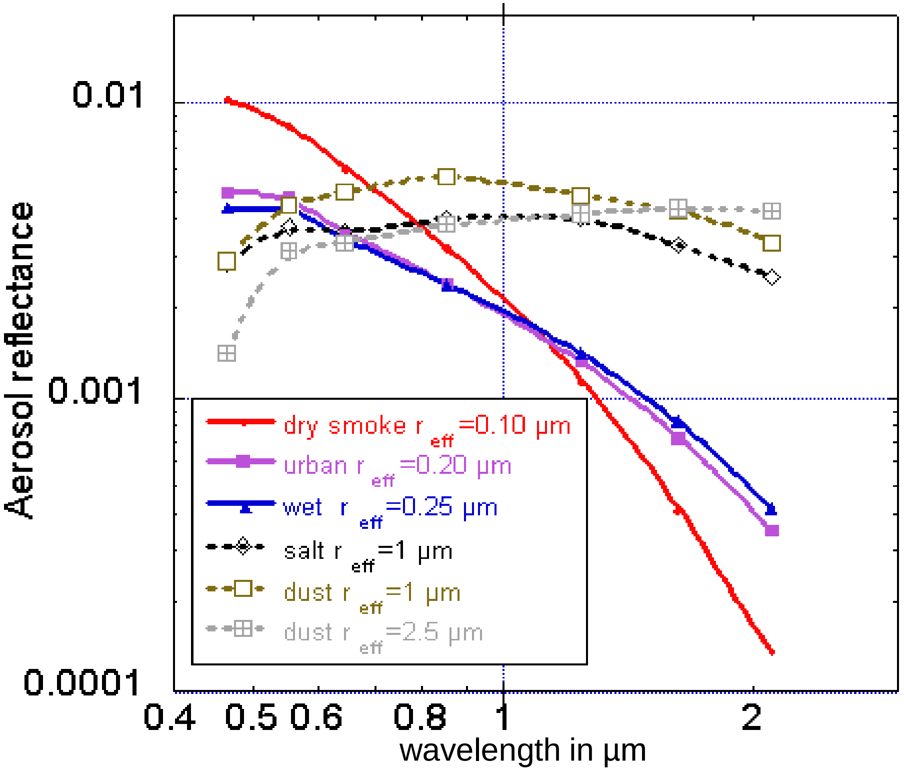
Physical Properties

The angstrom exponent really represents the slope of the spectral response.

For measurements of optical thickness

$\tau_{\lambda 1}$ and $\tau_{\lambda 2}$ taken at two different wavelengths λ_1 and λ_2

$$\alpha = -\frac{\ln \frac{\tau_{\lambda_1}}{\tau_{\lambda_2}}}{\ln \frac{\lambda_1}{\lambda_2}}$$

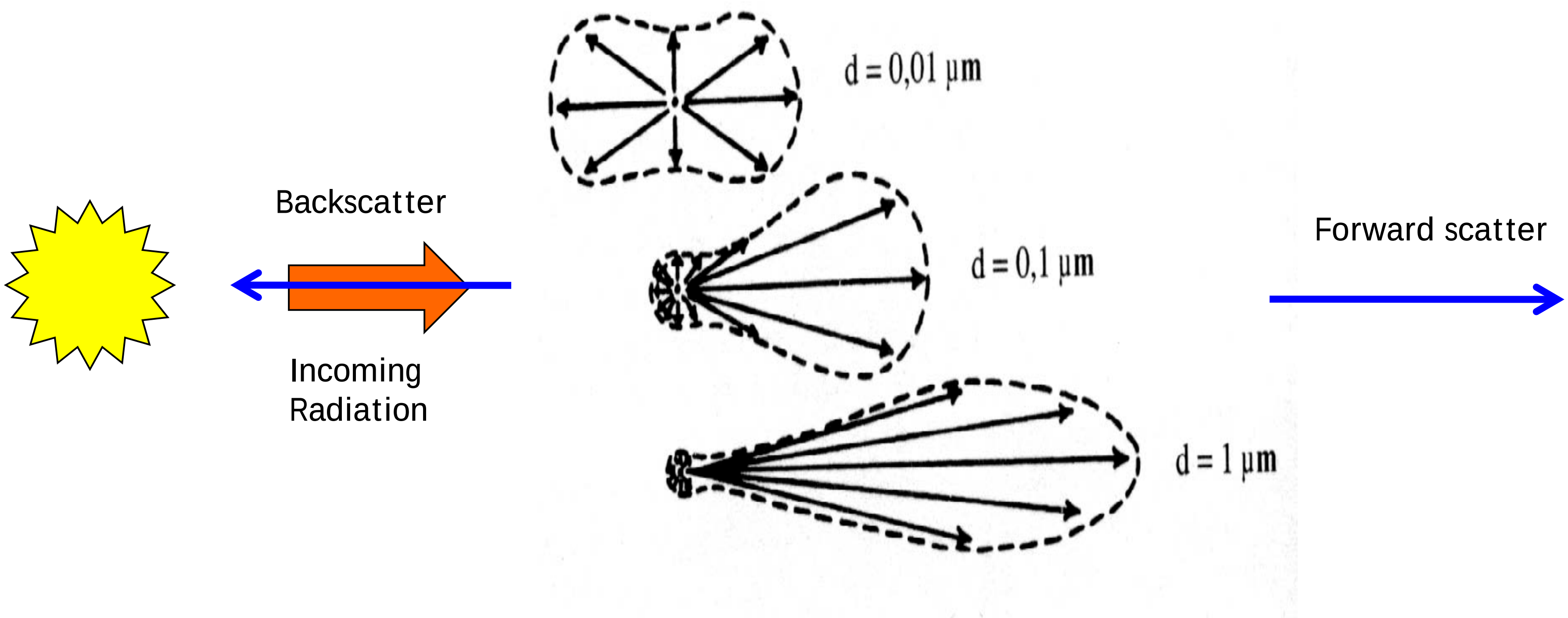


End Part 2

Optical Properties

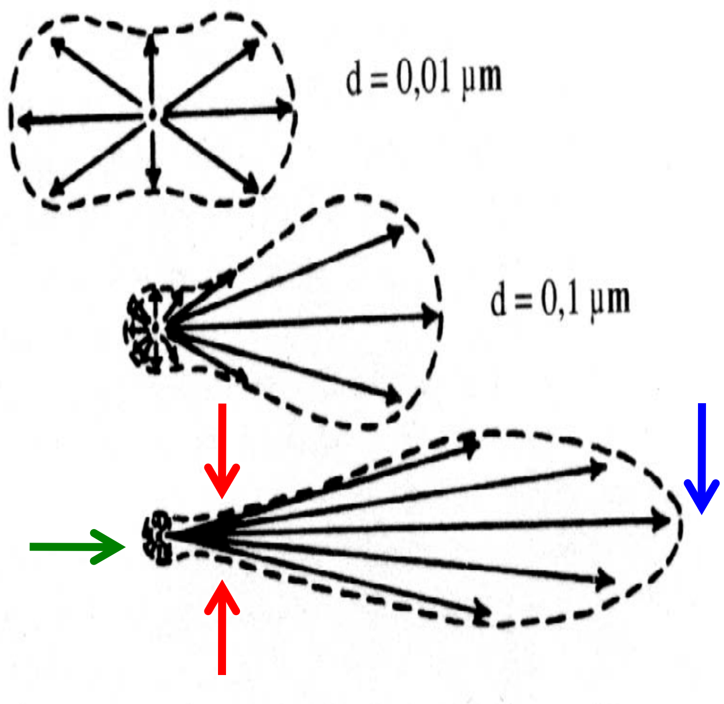
Scattering Phase Function

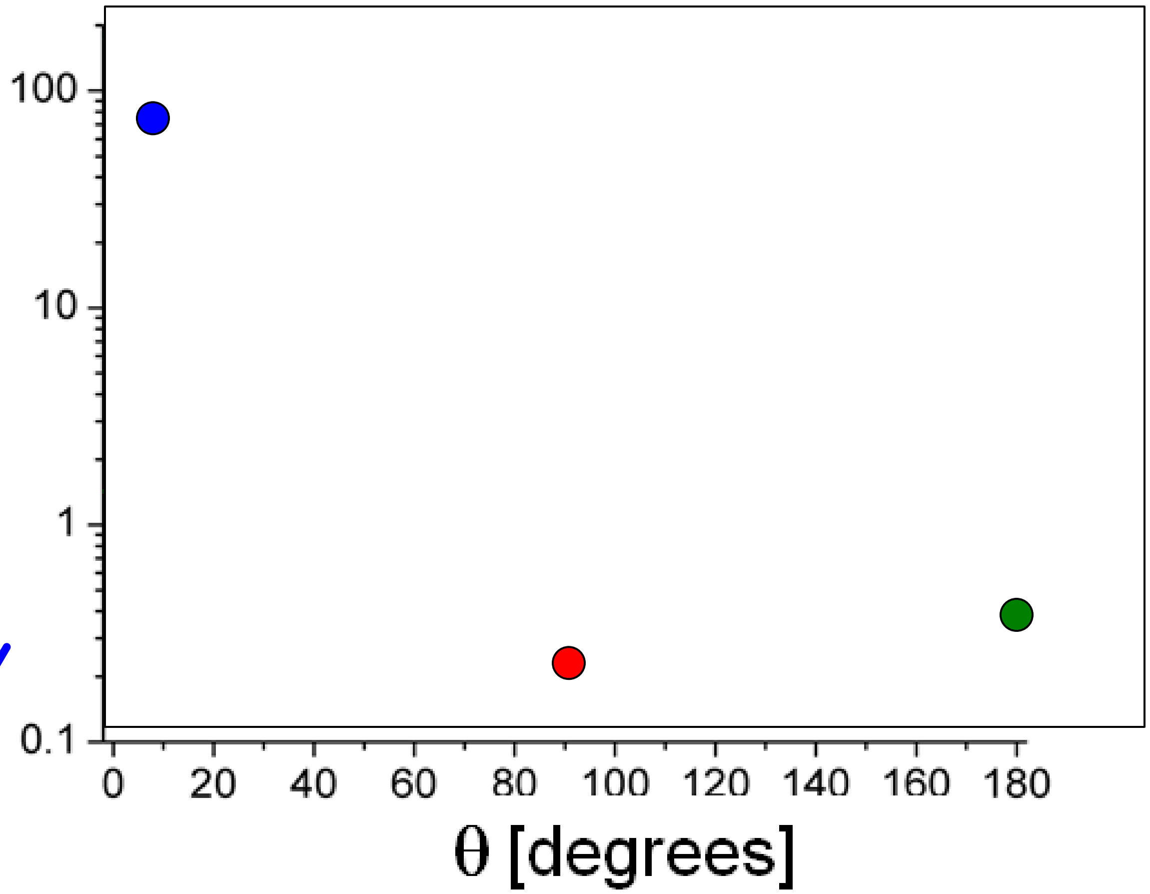
The directional light scattering due to the aerosol particles



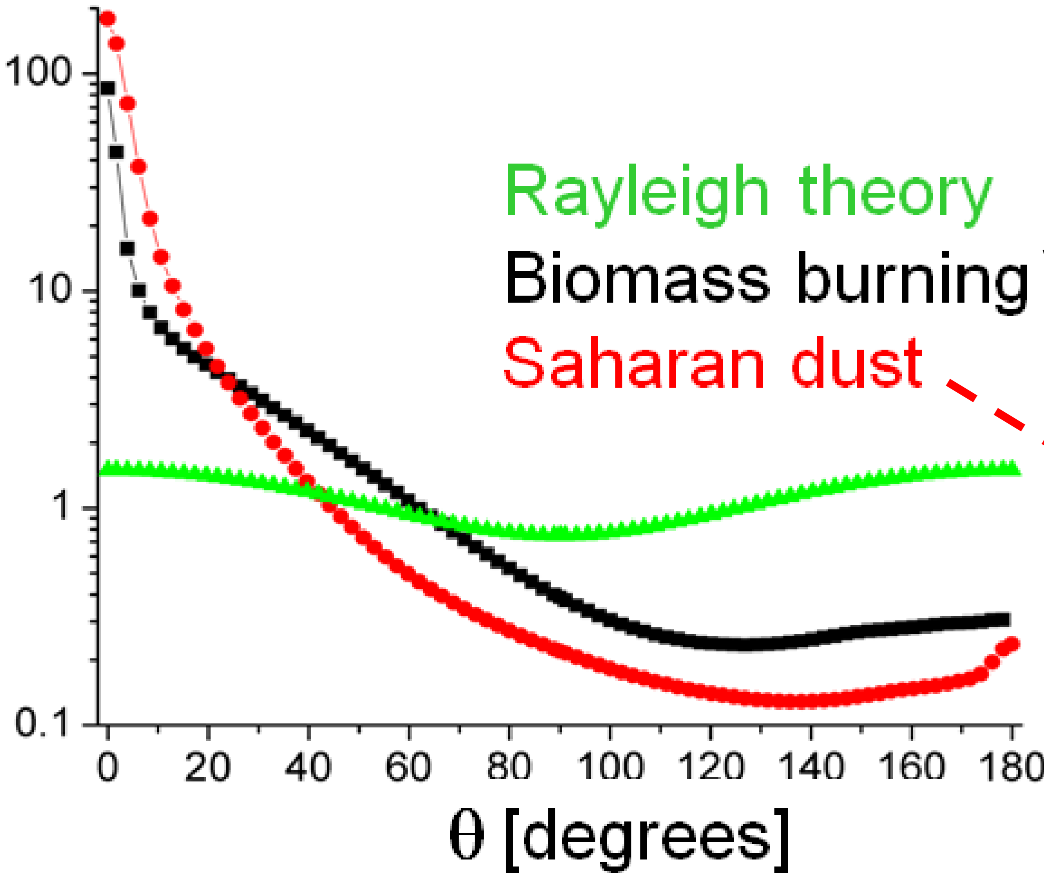
Optical Properties

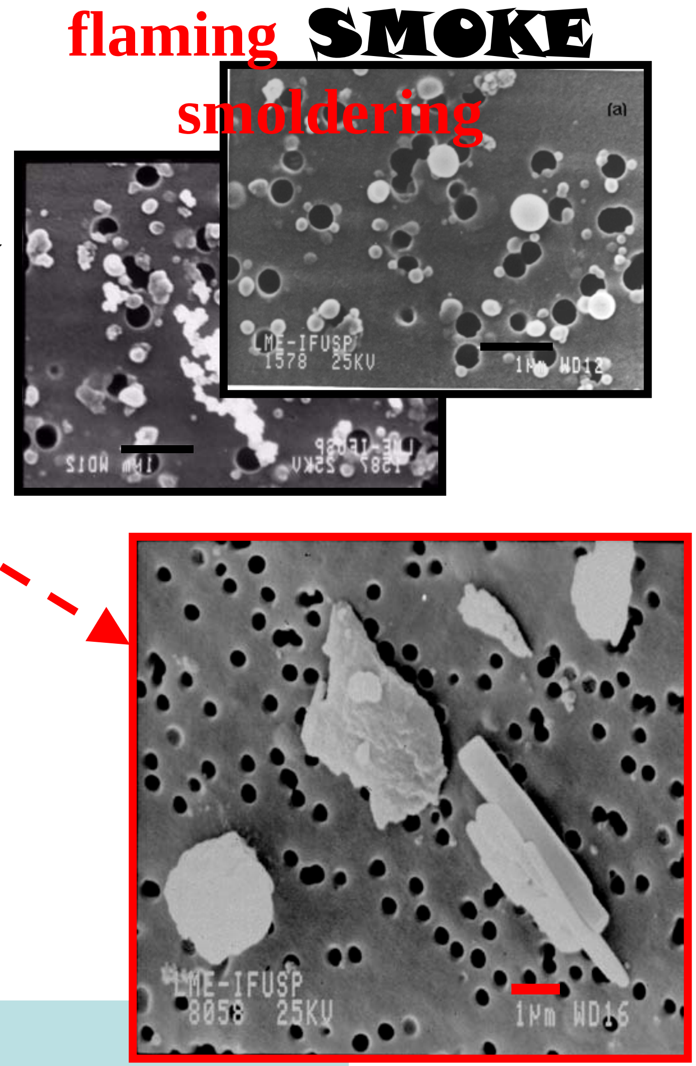
Scattering Phase Function – the amount of light scattered in each direction relative to the incoming direction.





Typical aerosols and their properties



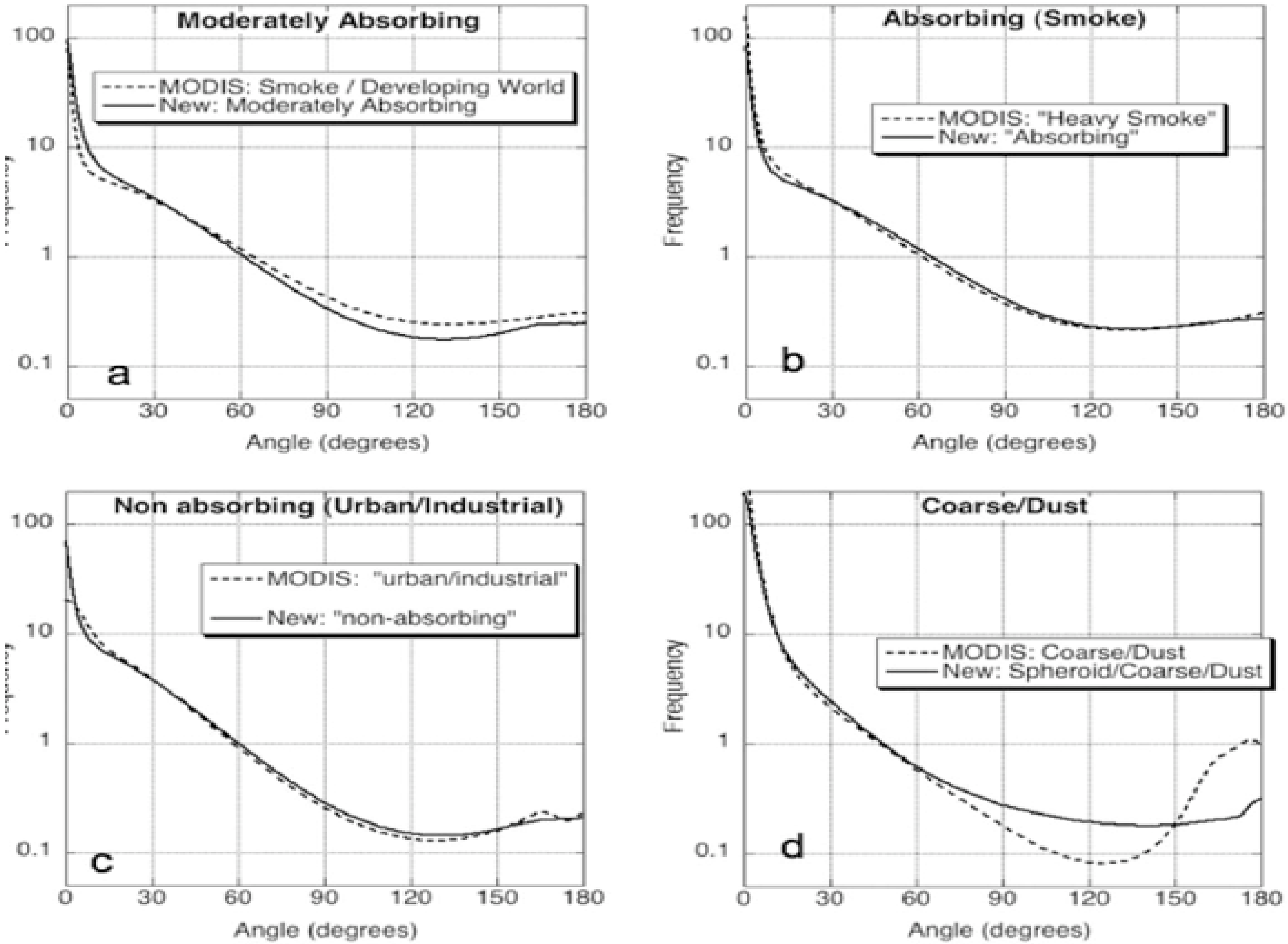


The phase function:

- relative angular distribution of scattered light
- heavily depends on the size and shape of aerosol particles

Optical Properties

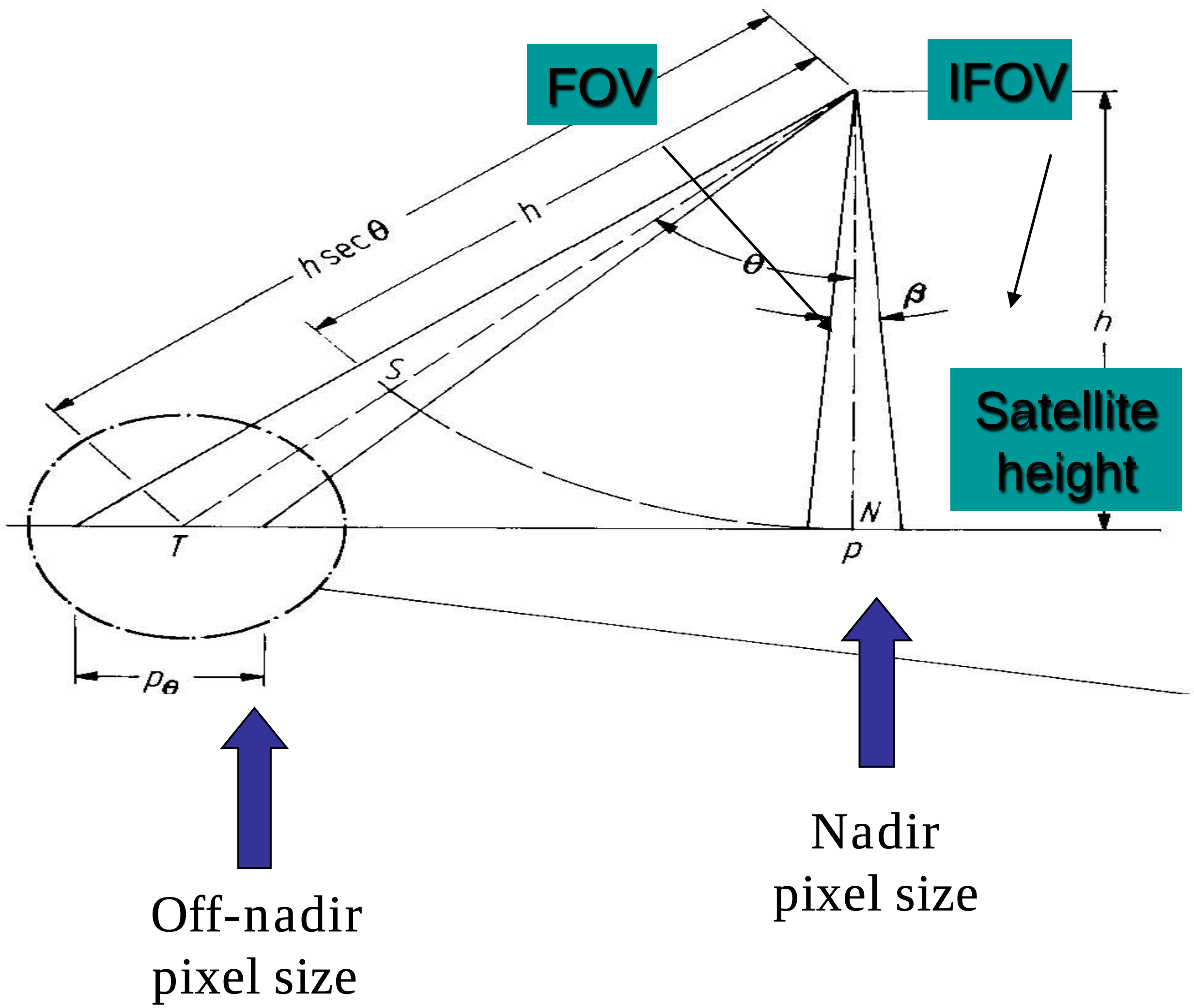
Sample Phase Functions



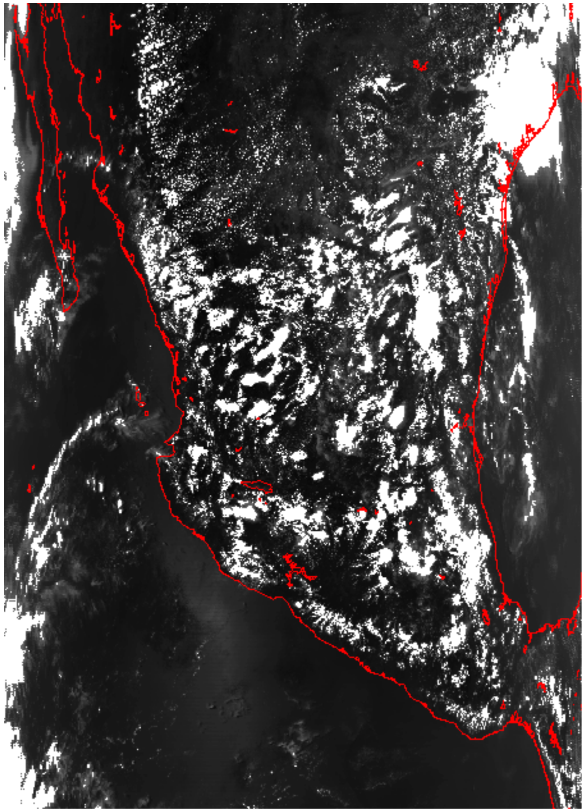
A few additional points

Spatial Resolution

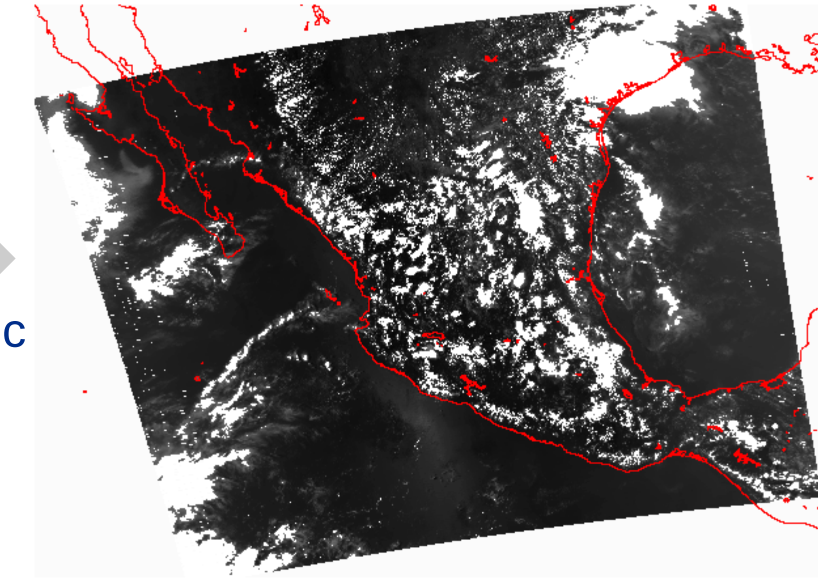
- Spatial Resolution : A simple definition is the pixel size that satellite images cover.
- Satellite images are organized in rows and column called raster imagery and each pixel has a certain spatial resolution.

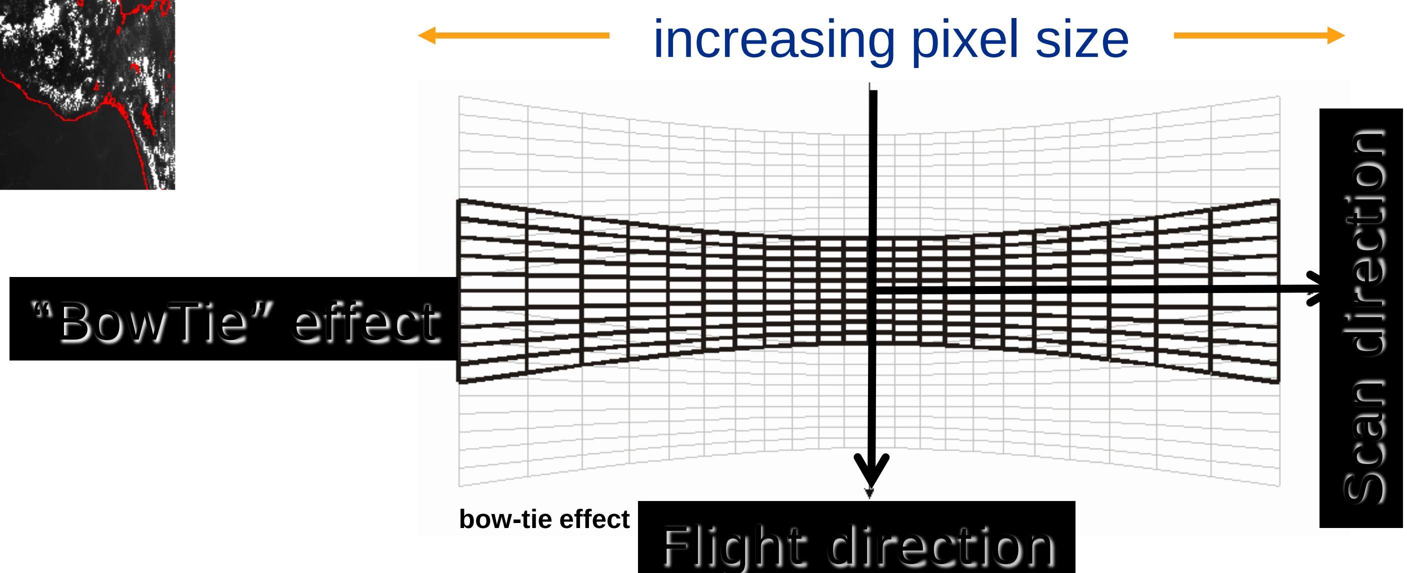


Native satellite view vs. map projection



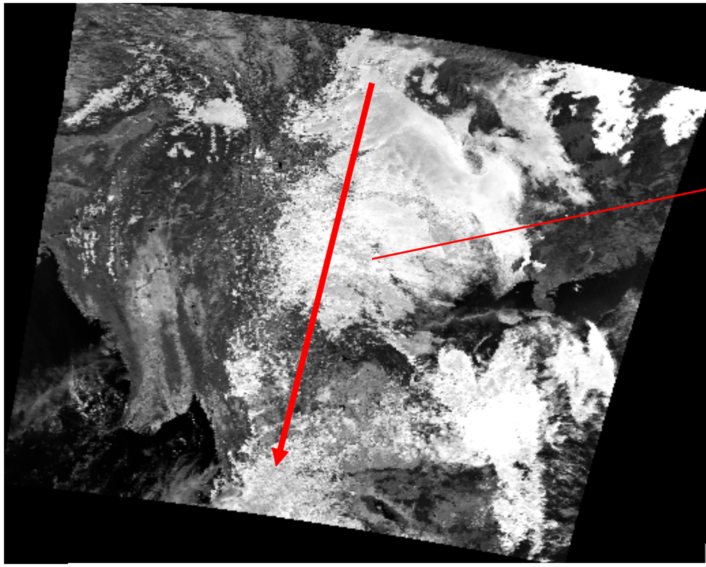
cylindrical isotropic projection





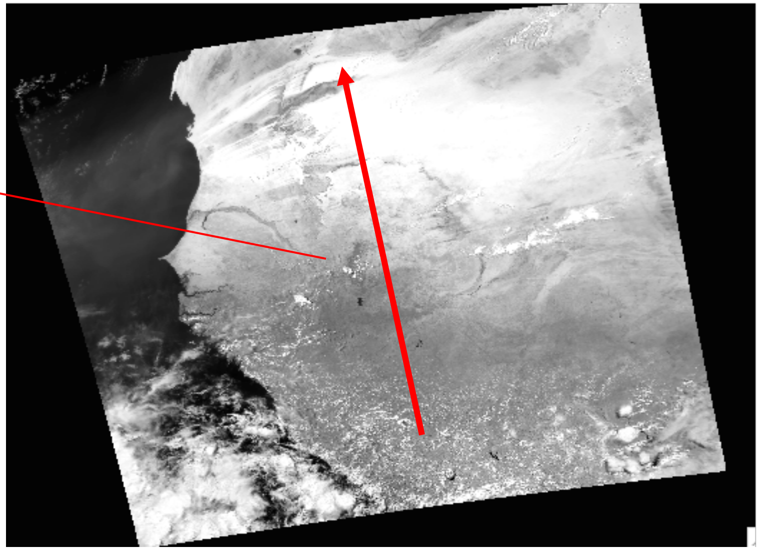
Terra Reprojected Granule

~10:30 Local Time



AQUA Reprojected Granule

~1:30 Local Time



Flight Direction of the Overpass Gives a “Tilt” to the reprojected granule

ALWAYS CHECK YOUR DATA VISUALLY!

Time 0 Min

Time 5 Min